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Prevalence of insect pests in large cardamom (*Amomum subulatum* Roxb.) and evaluation of bio-rationals for the management of major pests under organic agro-ecosystem of Sikkim

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Abstract

Large cardamom (*Amomum subulatum* Roxb.) is one of the important cash crops of Sikkim and Darjeeling areas of West Bengal. In this study, a fixed plot survey on insect pests of large cardamom was conducted and found that stem borer (*Glyphipterix* spp., Lepidoptera: Glyphiperidae), shoot fly (*Merochlotops dimorphus* Cherian, Diptera: Chlororpidae), leaf eating caterpillar (*Artona chorista* Jordon, Lepidoptera: Zygaenidae) and tea mosquito bug (*Helopeltis theivora* Waterhouse, Hemiptera: Miridae) are the major pests of the crop. Eco-friendly organic treatments like neem-based oil, petroleum-derived horticultural oil, spinosad and different formulations of entomopathogens were tested against these major insects. Among all, application of spinosad 45 SC @ 0.3 ml L^{-1} was found effective followed by neem-based oil (Azadirachtin 0.15% EC) 1500 ppm @ 3 ml L^{-1} at three different time intervals (first application in February-March, second application in June-July and third application in October-November) against all insects. Moreover, entomopathogenic bio-control agents (*Bacillus thuringiensis* @ 2 ml L^{-1}, *Metarhizium anisopliae*@ 5 ml L^{-1} and *Beauveria bassiana* @ 5 ml L^{-1}) were on par with neem-based oil for the management of stem borer. Considering the economic importance of the crop and absence of valid technology for management of insect pests in large cardamom through organic options, application of either of them could be helpful in organic management of insect pests in Sikkim.

Keywords: Bio-rationals, large cardamom, management module, organic, pest, Sikkim.

Introduction

Large cardamom (*Amomum subulatum* Roxb.), known as 'badi elaichi' in Hindi, is the principal perennial cash crop in the Eastern Himalayan region of India (Sikkim and the Darjeeling hills), eastern part of Nepal and Southern Bhutan (Sharma *et al*. 2016). India, being second largest producer, contributes about 37% of the world's production after Nepal (53%) (Subedi *et al*. 2014). Sikkim produces around 5030 MT from approximately 23312 ha of area (www.indiastat.com 2019) with productivity of 260-280 kg ha^{-1} (Deka *et al*. 2016). In the recent times, the area of large cardamom has spread to other North Eastern Indian states like Nagaland (6308 ha), Arunachal Pradesh (9901 ha), Mizoram (400 ha), Meghalaya (250 ha), Manipur (250 ha) and Uttarakhand (41 ha) (www.indiastat.com, 2019; Uma *et al*. 2014). It is used in different forms as spice or condiment, flavoring agent, preventive and curative agent for sore throat, lung congestion, digestive disorders, and pulmonary tuberculosis in Unani and Ayurvedic medicine (Sharma *et al*. 2009).

Although the crop has significant importance globally, the occurrence of pests causes economic loss to the farmers (Deka *et al*. 2016; Saju *et al*. 2013). A total of 21 insect species have been reported to cause minor to major damage in large cardamom; of them stem borer (SB) (*Glyphipterix* spp., Lepidoptera: Glyphiperidae) and leaf eating caterpillar (LEC) (*Artona chorista* Jordon, Lepidoptera: Zygaenidae), specific to this crop, are considered as the most serious pests (~40% damage) (Thakur 1981; Thakur & Sachan 1987; Pangtey & Thakur 1986). The other important insect pests are shoot fly (SF) (*Merochlotops dimorphus* Cherian, Diptera: Chlororpidae), white grub (WG) (*Holotrichia* spp., Coleoptera: Melolonthidae), tea mosquito bug (TMB) (*Helopeltis theivora* Waterhouse, Hemiptera: Miridae), mealybug (MB) (*Paraputo theaecola* Green, Hemiptera: Pseudococcidae) and aphid (*Pentalonia nigronervosa* Coquerel, Hemiptera: Aphididae, *Micromyzus kalimpongensis* Basu, Hemiptera: Aphididae and *Aulacorthum solani* Kalt, Hemiptera: Aphididae) (Deka *et al*. 2016; Dhanapal *et al*. 2018; Gudade *et al*. 2013).

Several indigenous technical/traditional knowledge (ITKs) related to pest management in large cardamom have been reported in Sikkim (Gopi *et al*. 2016; Laxuman *et al*. 2017; Pradhan *et al*. 2017). However, there is no report of evaluation of organically permitted/accepted mineral oil, neem-based oil, bio-pesticides or reduced risk insecticide formulations like spinosad against large cardamom pest populations till date. Bio-rationale agents and approaches will be the key for elevating our IPM strategies for pest management in organic farming of Sikkim. Considering the global importance of crop, the present study was aimed towards selection of major pest of large cardamom and evaluation of eco-friendly treatments like neem-based oil, petroleum-derived horticultural oil, spinosad and different formulations of entomopathogens for the management of insect pests occurring on the crop.

Materials and methods

Selection of site, pre-treatment surveillance and treatment design

The study was conducted at the Research Farm of ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok, India (latitude 27°19'27.16'' N, longitude 88°36'0.33'' E, altitute-1200 m amsl). The soil of site is mainly represented as sandy loam having soil pH ~5.3 and mean soil organic carbon 1.14 %. The annual rainfall in previous three years ranged from 2894.1 mm to 3322.2 mm with highest relative humidity of 91.5% in July and minimum relative humidity of 37.7 % in January (Figure 1). The average maximum temperature in the past three years was about 24.6 °C whereas the average minimum temperature was 15°C (Figure 1). Fixed plot surveillance (pre-treatment) was conducted at monthly interval through random sampling in large cardamom plantations and number of infested shoots $leaves^{-1}$ $clump^{-1}$ was noted and per cent incidence for each pest was derived.

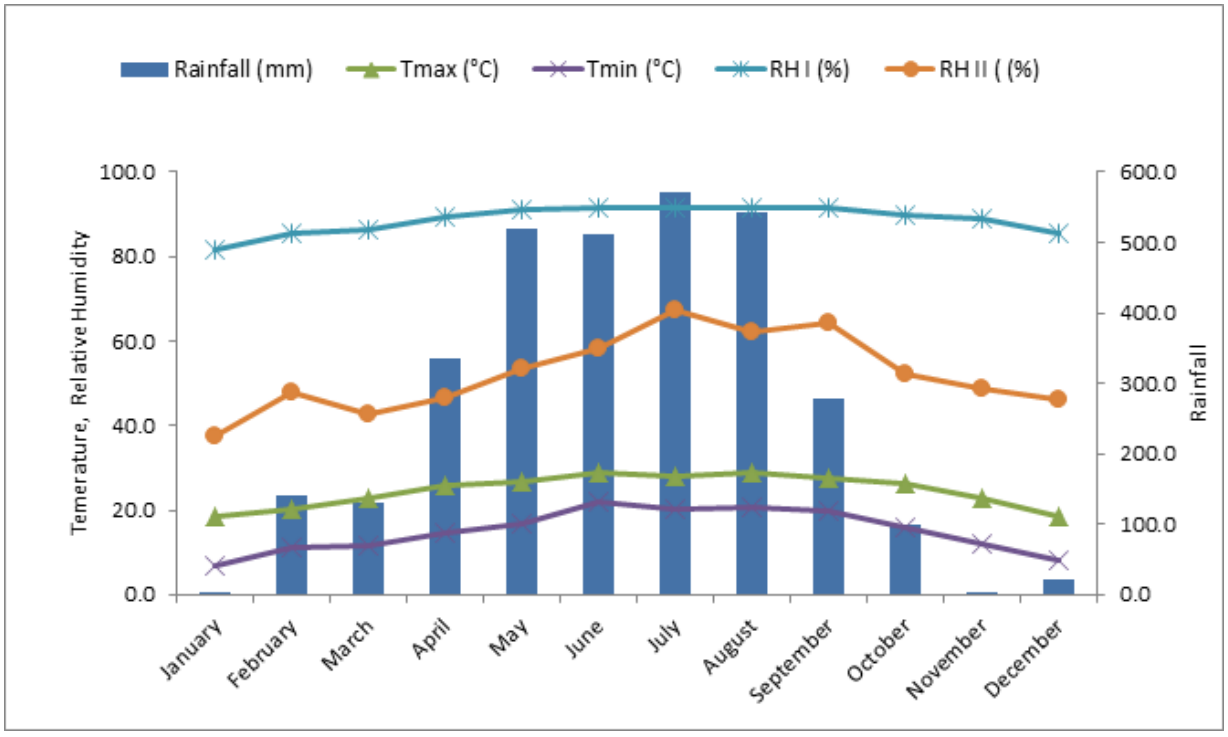

Figure 1: The graphical presentation of environmental factors (rainfall, maximum temperature, minimum temperature, relative humidity) of study site over three years

The experiment was conducted on three-year old *Sawney* cultivar of large cardamom having spacing of 1.5 m × 1.5 m in Randomized Block Design with three replications (nine clumps rep^{-1}). Plantation was maintained with necessary organic management practices with respect to intercultural operations like weeding, manuring *etc*.

Organic treatments

Seven organic treatments (commercial products): neem-based oil (Azadirachtin 0.15% EC) 1500 ppm @ 3 ml L^{-1}, *Beauveria bassiana* (1× 10^{8} CFU ml^{-1}) @ 5 ml L^{-1}, *Metarhizium anisopliae* (1× 10^{8} CFU ml^{-1}) @ 5 ml L^{-1}, *Akanthomyces lecanii* (1× 10^{9} CFU ml^{-1}) @ 5 ml L^{-1}, petroleum-derived horticultural oil (comprised of paraffinic base oil and emulsifiers) @ 10 ml L^{-1}, *Bacillus thuringiensis var. kurstaki serotype 3a, 3b, SA II WG* @ 2 g L^{-1}, *spinosad* 45% *SC* @ 0.3 ml L^{-1} along with control were evaluated in large cardamom plantations against natural populations of SB, SF, LEC and TMB at three different time intervals, first application in February-March, second application in June-July and third application in October- November. The treatment dosages were prepared as per the recommended dose in separate buckets. Manually operated Aspee knapsack sprayer of 15 litre capacity was used for spraying of insecticides (2017-19). The control plot was sprayed with water during each spray.

The incidence of SB, SF, LEC and TMB was recorded based on the characteristics symptoms (SB- holes in shoot with extruded excreta; SF- browning and drying of shoot tip; LEC- skeletonization and defoliation of leaves and TMB- brown streak stain on leaves) of pest on shoots/leaves of the clump (Kalita *et al*. 2016; Vijayan *et al*. 2019). The percentage of infested shoot in each clump was calculated based on the formula

$$PI = \frac{\text{Total number of affected shoots or leaves per clump}}{\text{Total number of shoots or leaves per clump}} \times 100$$

The per cent reduction over control (PROC) was calculated as

$$PROC = \frac{C-T}{C} \times 100$$

Where, C: percentage damage of large cardamom in control plot and T: percentage damage of large cardamom in treated plot.

Pre-treatment observations on pest and damage level were made before spraying. The observations were recorded seven days after final spraying on nine clumps of large cardamom in each of the three replications. PROG GLM was used for the analysis of variance for each year and each character individually. The class variables were treatments and replications, which means the analysis is done for a two way classified data (or RCB design). The homogeneity of error variances was tested by F-test. After assessing the homogeneity, the data were pooled and subjected to a two way ANOVA with treatment, year, and the interaction as fixed effects using PROG GLM of SAS software package, version 9.4 (SAS Institute, Cary, North Carolina, USA). As year and year x treatment interactions were non-significant for all variables, only the treatment effect was reported with means averaged across years. Tukey's Honest Significant Difference (HSD) test was used to separate means.

Results and discussion

In general, large cardamom plantations of Sikkim frequently witnessed SB, SF, TMB, LEC, WG, aphid and MB during the month of February after rise in temperature, relative humidity and rainfall after severe winter. Gradually populations of these pest increase with increase in rainfall and RH and reach maximum by July as rainfall and relative humidity reach maximum, decreases after rain recedes till October followed by diapauses. In the present study, the occurrence of *H. theivora* was maximum (30.52%) followed by *A. chorista* (24.5%), *Glyphipterix* spp. (19.5%) and *M. dimorphus* (18.75%). The incidence of other pests like mealybug, aphids and white grub were below 10% (Table 1). Large cardamom has been reported to be infested with three major insect pests *viz.*, stem borer (*Glyphipterix* spp.), shoot fly (*M. dimorphus*) and leaf caterpillar (*A. chorista*) during surveys at Sikkim and Darjeeling district of West Bengal (Deka *et al*. 2016; Dhanapal *et al*. 2018; Gudade *et al*. 2013). Among the three, *M. dimorphus* was found to damage the large cardamom plantations upto 72.0% followed by *Glyphipterix* spp. (~24%) and *A. chorista* (~20%) in Pangthang and Kabi areas of East Sikkim. Moreover, *A. chorista* infestation was recorded high (~28%) in Darjeeling district of West Bengal as compared to Sikkim (Deka *et al*. 2016). Recently, the large cardamom plantations in Sikkim have recorded the

Table 1. Prevalence of insect pests in large cardamom plantations

Common Name	Scientific name	PI (%)
Shoot borer	*Glyphipterix* spp.	19.50
Shoot fly	*Merochlotops dimorphus* Cherian	18.75
Leaf eating caterpillar	*Artona chorista* Jordon	24.50
Tea mosquito bug	*Helopeltis theivora* Waterhouse	30.52
Mealy bug	*Paraputo theaecola* Green	9.75
White grub	*Holotrichia* spp.	5.76
Aphid	*Pentalonia nigronervosa* Coquerel, *Micromyzus kalimpongensis* Basu and *Aulacorthum solani* Kalt. *Mollitrichosiphum* spp.	9.48

PI- Per cent Incidence (Mean value of all observations)

occurrence of *Helopeltis theivora* Waterhouse infestation, which was earlier the major pest of tea and cashew (Ambika *et al.* 1979; Mahapatro (2008)) and caused nearly 30-35% damage in the leaves with symptoms resembling the leaf streak disease (Kalita *et al*. 2016).

The screening results of the biorationale pesticides against the insect-pests revealed that treatments have significant effect in reducing the damage caused by major insects across the years. However, year and year x treatment interactions had no significant effect on the insects and pests (Table 2). Among the treatments, spinosad 45 SC@ 0.3 ml L^{-1} was found most effective with maximum per cent reduction over control (PROC) (64.51 ± 9.54%) followed by neem-based oil (Azadirachtin 0.15% EC) 1500 PPM @ 3 ml L^{-1} with PROC ranging from 54.39 ± 8.69 % (Table 3). Moreover, entomopathogenic bio-control agents (*Bacillus thuringiensis* @ 2 ml L^{-1}, *Metarhizium anisopliae*@ 5 ml L^{-1} and *Beauveria bassiana* @ 5 ml L^{-1}) showed on par result with neem-based oil against the shoot borer. As per national guidelines of organic farming, Government of Sikkim warrants the use of biorational pesticides derived from natural source which impose no adverse threats to the environment or beneficial organisms. After ascertaining the product development and certification of organic input from certified suppliers, Sikkim Government decides to purchase the bio-rationals or organic insecticides and provides to farmers free of cost to maintain the quality of organic products. Therefore, the present study included organically accepted sources like spinosad, petroleum-derived horticultural oil, entomopathogens and neem-based oil (Azadirachtin 0.15% EC). Spinosad is a natural pesticide of bacterial origin which was first isolated from *Saccharopolyspora spinosa* (Actinomycetales) (Mertz & Yao, 1990). The efficacy of spinosad in the management of various insect-pests in organic conditions has been well known (Balasaheb (2015); Herbert *et al*. 1998; Janaki *et al*. 2011; Overall (2008). Although this product has never been claimed to manage large cardamom insect pest earlier, it has been successfully used to manage tomato fruit borer in Sikkim (Kalita *et al*. 2017). In another study, *Sciothrips cardamomi* (cardamom thrips) (Thripidae) and *Conogethes punctiferalis* (shoot borer) (Crambidae) have been controlled by application of spinosad (Jacob *et al*. 2015; Senthil Kumar *et al*. 2017, 2019). In the present study, the spraying was avoided during flowering time (April and May) of cultivar "*Sawney*" to avoid any impact on pollinators despite the fact that insects were present during April and May.

In our study, *M. anisopliae*, *B. bassiana* and *B. thuringiensis* exhibited management of lepidopteran and dipteran pests like SB, SF, LEC up to 49.56 ± 7.98 % PROC (Table 3). The petroleum-derived horticultural oil @ 10 ml L^{-1} showed efficacy against tea mosquito bug (40.44 ± 5.65 % PROC) under field conditions which was comparable to neem based oil (Azadirachtin 0.15% EC) (42.54 ± 5.94 % PROC). The association of entomopathogens

Table 2. Two way analysis of variance (F value and level of significance) of per cent reduction over control of different treatments over three years

Source	Year	Treatment	Year x Treatment
Shoot borer damage	3.1 (0.06)	29.37 (<.0001)	0.59 (0.83)
Shoot fly damage	17.18 (<.07)	48.89 (<.0001)	0.66 (0.78)
Leaf eating caterpillar damage	1.73 **(**0.19)	25.26 (<.0001)	0.26 **(**0.99)
Tea mosquito bug damage	1.94 (0.16)	130.23 (<.0001)	0.21 (0.99)

F value and prob.>F (in parenthesis). The critical value for year, treatment and year x treatment are F (2, 40), F (6, 40) and F (12, 40) respectively; Homogeneity of error variance over years was tested using F test.

Table 3. Per cent reduction over control of biopesticides and organically permitted insecticides on shoot borer, shoot fly, leaf eating caterpillar and tea mosquito bug incidence in large cardamom over three years

Treatment	Dose ml L^{-1}	SBD	SFD	LECD	TMBD
Neem-based oil (Azadirachtin 0.15% EC) 1500 ppm	3.0	54.39 ± 8.61^{ab}	53.88 ± 9.11^{b}	51.82 ± 8.87^{ab}	42.54 ± 5.94^{b}
Beauveria bassiana	5.0	43.87 ± 7.43^{bc}	44.34 ± 7.86^{c}	43.02 ± 7.17^{b}	13.24 ± 3.95^{c}
Metarhizium anisopliae	5.0	49.44 ± 8.66^{b}	49.56 ± 7.98^{bc}	48.09 ± 8.18^{b}	10.08 ± 1.41^{c}
Akanthomyces lecanii	5.0	24.69 ± 4.67^{d}	24.43 ± 6.02^{e}	23.2 ± 4.55^{c}	8.76 ± 1.22^{c}
Petroleum-derived horticultural oil	10.0	33.77 ± 5.19^{cd}	32.80 ± 5.41^{d}	31.29 ± 5.69^{c}	40.44 ± 5.65^{b}
Bacillus thuringiensis	2.0	49.77 ± 9.02^{b}	50.29 ± 9.58^{bc}	48.73 ± 8.61^{b}	12.1 ± 1.69^{c}
Spinosad	0.3	64.51 ± 9.54^{a}	63.58 ± 11.03^{a}	60.87 ± 10.06^{a}	51.95 ± 7.26^{a}
Tukey's MSD at 5% level of significant		10.70	8.28	11.56	7.13

SBD-Shoot borer damage; SFD- Shoot fly damage; LECD-Leaf eating caterpillar damage; TMBD-Tea mosquito bug damage

The values are means ± SD. Means with same alphabet in the column are not significantly different as per Tukey's HSD at $P \leq 0.05$.

Total cost includes cost of spray and labor charges

viz., *Cladosporium* sp, *Metarhizium* spp. *Penicillium* spp. and *Akanthomyces* spp., with dead *A. chorista* (LEC) larvae have been reported in Sikkim (Deka *et al*. 2016) of which *Cladosporium* spp. was found promising under laboratory conditions. Horticultural oils derived from petroleum have been considered as the safest and effective insecticides on soft bodied insects. Field application of petroleum-derived agro spray oil significantly managed the mite population in tea due to ovicidal and repellent properties (Roy *et al*. 2015).Therefore, in conclusion, it was found that spinosad 45% SC @ 0.3 ml L^{-1} was most effective against all pests of large cardamom followed by neem oil (Azadirachtin 0.15% EC) 1500 PPM @ 3 ml L^{-1} at three different time intervals (first application during February-March, second application in June-July and third application in October-November). Sikkim, being an organic farming state, is in need to find alternatives for chemical pesticides which are considered to be environmentally unsafe. Hence, the findings of this study will be useful for large cardamom farmers to manage the pests in a sustainable and eco-friendly way.

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